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OBSERVING BEHAVIOR IN SQUIRREL MONKEYS UNDER A MULTIPLE SCHEDULE OF REINFORCEMENT AVAILABILITY[1]

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Observing behavior of two squirrel monkeys was examined under a multiple schedule of four components. Lever (observing) responses produced either a stimulus indicating the availability of food or another stimulus indicating food was not available. Key responses in the presence of the food-available stimulus produced food on a continuous reinforcement schedule. In the absence of food-available stimuli, responding on the key had no scheduled consequences. Observing responses produced food-available stimuli according to three different random-interval schedules with mean interstimulus availability times of 1, 2, and 4 min. In the fourth component of the multiple schedule (observing extinction) food-available stimuli never occurred. Each component of the schedule was correlated with a distinctive auditory stimulus. Observing rates decreased with decreasing frequency of the food-available stimulus. Observing rates during extinction continued decreasing when the brief stimulus indicating food unavailability was no longer produced by lever pressing. When the brief stimulus was reinstated response rates increased abruptly.

In a previous experiment (de Lorge, Hess, and Clark, 1967), squirrel monkeys were trained to press a lever (observing response) that intermittently produced a red light on a key. Responses on the key in the presence of a red light (S^D) produced food. Availabilities of S^D, and hence, of food, were arranged according to random-interval schedules. When food was not available, observing responses produced a different, brief stimulus on the key (S^Δ). This procedure generated high observing rates, short latencies of responding on the key in S^D, and few key responses in the absence of S^D. When the average frequency of S^D availabilities was decreased successively from 1 per min to 1 per 8 min observing response rates did not vary systematically.

The present experiment was undertaken to clarify the conditions responsible for insensitivity of observing response rates to the frequency of food-available signals in the earlier experiment. It has been expected that observing rates would decrease with decreasing S^D frequency. This would have been in agreement with experiments showing decreased operant response rates as a function of decreasing reinforcement rates under interval schedules (*e.g.*, Clark, 1958; Farmer, 1963; Herrnstein, 1961; Catania and Reynolds, 1968). In this regard, two possibilities were considered. First, continued exposure may render response rates insensitive to reinforcement frequency except where several schedules are alternately available, as in a multiple schedule, or where different reinforcement frequencies are simultaneously available, as under concurrent schedules (Catania, 1966; Herrnstein, 1961; Morse, 1966). Second, occurrence of the brief stimulus indicating unavailability of food could have had a role in maintaining observing responses (Gollub, 1970; Hendry, 1969; Hendry and Coulbourn, 1967; Schaub, 1969; Schaub and Honig, 1967).

The same kind of observing schedule as used previously was employed in the present experiment, except that a multiple schedule of S^D availability was used. Four different frequencies of S^D availability, each correlated with a distinctive stimulus, were presented in each session. Behavior under the multiple schedule was studied for an extended period. On two occasions, the stimulus indicating unavailability of food (S^Δ) was removed from particular schedule components and then reintroduced.

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METHOD

Subjects

Two adult male squirrel monkeys, *Saimiri sciureus,* were maintained at between 75% and 80% of their free-feeding weights. These monkeys, designated M4 and M8, had previously been used as subjects in a similar experiment (de Lorge *et al.,* 1967), which gave the animals extensive histories of responding under random-interval observing schedules. Both subjects had also been administered *d*-amphetamine without evidence of behavioral aftereffects (Clark, 1969).

Apparatus

Details of apparatus have been reported in de Lorge *et al.* (1967). Experimental cages were 10.75 in. high, 11.75 in. long, and 9.75 in. wide (27.3 by 29.8 by 24.8 cm) (modified Scientific Prototype Model A-103). Cages were housed in ventilated compartments and subjects could be observed through a wide angle lens. A transparent pushbutton response key (Grason Stadler, Model E8670A) was centered on one cage end 2.8 in. (7.3 cm) below the lid. The key could be illuminated with a red or green light through an in-line digital display. The observing lever was a Switchcraft lever switch mounted 2.75 in. (7 cm) below the pushbutton. The switch handle was a machined aluminum rod projecting 1.75 in. (4.5 cm) into the chamber. Directly below the lever was a dipper feeder (Ralph Gerbrands Model B). The food aperture was recessed and partially masked with clear plastic so that food could be obtained only with a paw. The feeder introduced about 0.3 ml of semiliquid into the aperture for 3 sec. Operation of the feeder illuminated the mask and aperture and turned off the house and keylights for the duration of the feeder cycle. Food was prepared from special Monkey Diet, SK&F (Nutritional Biochemicals, Inc.) by blending with water and cottonseed oil (de Lorge *et al.,* 1967). Depression of the key produced a relay click and, when reinforcement was available, operated the dipper feeder. Depression of the lever produced a click and produced stimuli on the key. Water was continuously available during experimental sessions and the cage was illuminated by two 3-w bulbs except during feeder operation.

Discriminative stimuli associated with different schedules of signal availability were a white noise, a clicker, and two different tones. The latter three were generated by a Foringer multiple stimulus panel, Model 1166-M1. Random-interval (RI) schedules of signal and reinforcement availability were generated by two precision probability gates in series (BRS Electronics, Model PP-1). The probability units were modified to modulate internal clock frequency with a voltage derived from a white noise source. Statistical properties and methods of arranging random-interval schedules have been described previously (Clark and Hull, 1965; de Lorge *et al.,* 1967). In this experiment, the probability (P) of an S^D and reinforcement becoming available in a 1-sec interval (T) was constant and independent of the time since the last availability. The four schedules used had mean interavailability times (T/P) of 1, 2, 4 min, and ∞ (extinction). Lower frequencies of signal availability were obtained by dividing the outputs of the RI 1-min schedule.

Procedure

Observing schedules were arranged so that pressing the lever (observing response) produced either a red or green light on the food key. When a green light was produced it remained for 0.5 sec, during which key responses had no scheduled consequence. When a red light was produced, a single response on the key terminated the light and operated the feeder. Red lights, once produced, remained on the key until a reinforced key response occurred. In the absence of observing responses the key remained dark. The availability of red lights, and hence, reinforcement of key responses, was controlled by the random-interval (RI) schedule in effect at the time. If reinforcement was scheduled, pressing the dark key resulted in food delivery even if an observing response was not emitted. In practice, however, this almost never occurred. Behavior under these schedules normally consisted of a train of observing responses each producing a brief green light, an observing response producing a red light, and a single key response followed by a feeder cycle.

The multiple schedule had four components: three random-interval schedules of S^D availability with mean interavailability times of 1, 2, and 4 min, and an extinction component. The three RI schedules occurred in a mixed order with each component remaining for 15 min. Each 15-min exposure of an RI schedule was followed by a 5-min extinction period. The order of schedules was: RI 2, EXT; RI 4, EXT; RI 1, EXT; RI 2, EXT; RI 1, EXT; RI 2, EXT; RI 4, EXT; RI 2, EXT; RI 4, EXT; RI 1, EXT; RI 4, EXT; RI 1, EXT. Except as noted below, observing responses during extinction continued to produce brief green lights indicating unavailability of food. Red lights were never produced during extinction and key responses were never reinforced. Stimuli correlated with four components of the multiple schedule were: RI 1-min, a high frequency tone; RI 2-min, a low frequency tone; RI 4-min, a clicker; and observing extinction, a white noise. These stimuli were presented continuously during the associated schedule components.

Because of their previous training under observing schedules, both subjects were placed directly on the multiple observing schedule. Experimental sessions were conducted five days per week, Monday through Friday, except when apparatus or other failures occurred. Animals' weights were maintained by controlled feeding on weekends and when sessions were missed. Sessions were 4 hr in duration.

When Monkey M4 had received 96 sessions and M8 95 sessions on the multiple schedule, the green light indicating unavailability of food was removed from the observing extinction component for 20 consecutive sessions. Except during extinction, observing responses continued to produce the 0.5-sec green light if food was not available. During extinction, observing responses produced no stimuli on the key. After 20 sessions, the contingency of the brief stimulus on the observing response was reinstated during extinction components. After 42 additional sessions, the brief green light indicating unavailability of food was removed from all components of the multiple schedule for five consecutive sessions, and then reinstated in all components. The sequence of treatments comprised a total of 170 sessions.

RESULTS

Cumulative records of the observing behavior of two monkeys after extended training under the multiple schedule are presented in Fig. 1 and 2. In each case, a complete 4-hr session is shown. The ninety-sixth session of Monkey M4 is in Fig. 1, the ninety-fifth session of M8 in Fig. 2. Records have been rearranged to collect performance in successive exposures of each schedule. Each row contains the four 15-min exposures of one random-interval schedule, together with the 5-min observing extinction periods that followed each schedule exposure. These records are typical of the preceding 10 sessions of each subject.

Figure 1 shows about the same observing rate for M4 under RI 1-min and RI 2-min. When the schedule was RI 4-min, the observing rate was substantially lower, and during extinction observing responses were even more infrequent. A progressive decrease in observing rates with elapsed time can also be seen in Fig. 1 under all three RI schedules. A decrement with elapsed time, however, did not occur during observing extinction.

Typical observing performance of M8 appears in Fig. 2 and shows effects similar to those in Fig. 1. Observing rates decreased with decreasing reinforcement availability beyond RI 2-min. Figure 2 also shows a progressive decrease in rate throughout the session under all schedules, including observing extinction. M8's observing rate was lower than that of M4 under all schedules except extinction.

The development of observing response rates as a function of the number of sessions is shown in Fig. 3 (Monkey M4) and Fig. 4 (Monkey M8). These figures show the mean observing rate in each component of the multiple schedule as a function of the cumulative number of sessions. Except as indicated on the abscissa, each point is the mean of 10 sessions. At A in Fig. 3 and 4, the brief green light indicating unavailability of food (S^{Δ}) was eliminated from the extinction component for 20 sessions and then reinstated. At B, the green light (S^{Δ}) was eliminated from all components for five sessions and then reinstated.

The most obvious development in Fig. 3 and 4 is the gradual reduction in response rate during observing extinction. Response rates of both subjects declined in extinction for nearly 100 sessions (20 weeks). Observing rates in the other schedule components also decreased over the same period. These decreases were larger in Monkey M4 (Fig. 3). Except for the extinction component, how-

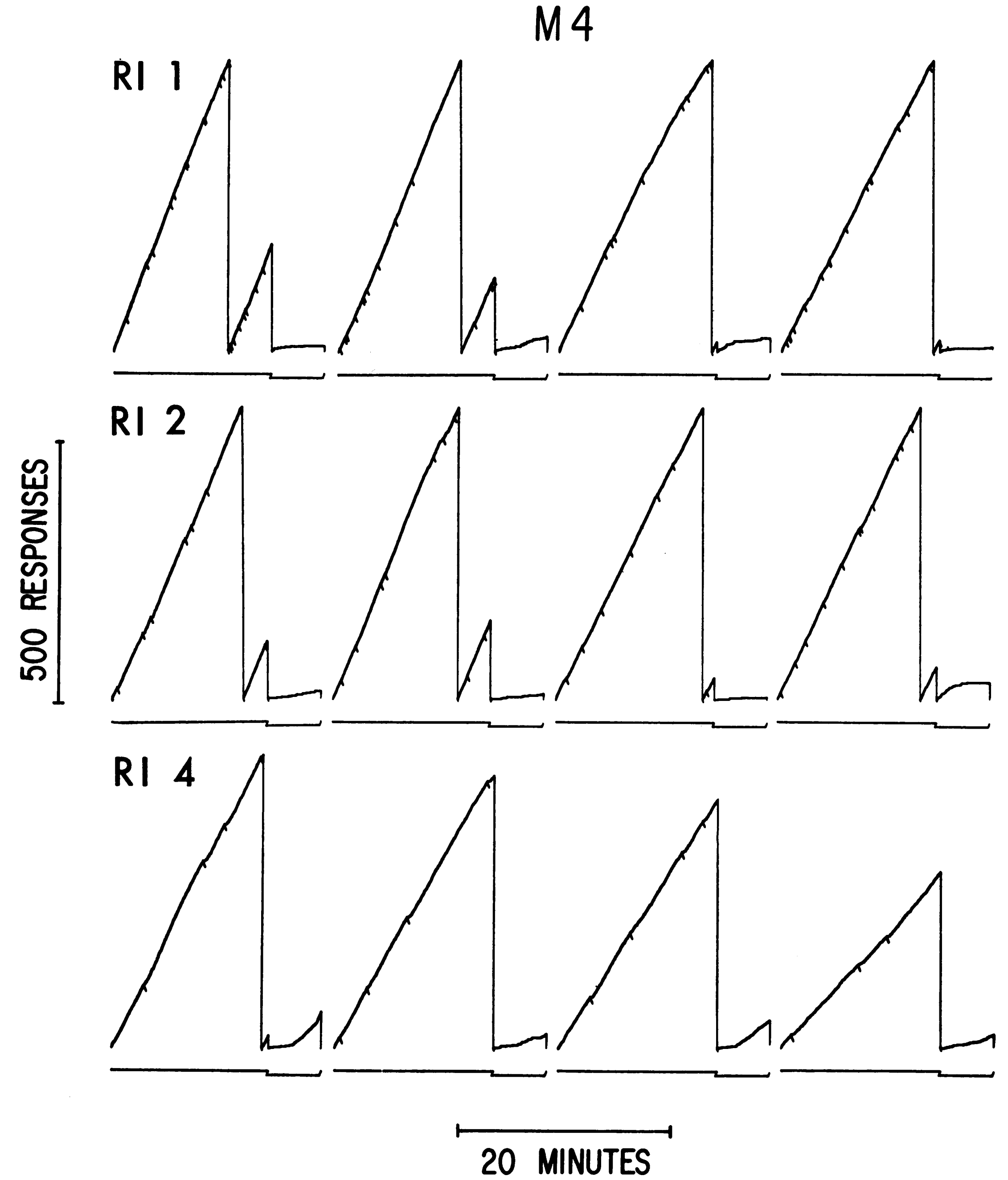

Fig. 1. Observing performance of Monkey M4 during the ninety-sixth session under the multiple schedule. The entire session is shown but the record has been rearranged to group successive occurrences of each schedule of S^D availability. The top row shows the four exposures to RI 1-min in order of their occurrence. Similarly, the second and third rows show the successive exposures of RI 2-min and RI 4-min, respectively. The actual mixed order of occurrence of the schedules is given in the text. A 5-min period of observing extinction follows each exposure of the other three schedules (event pen displaced). The cumulative recorder was reset after about 550 responses and at the end of each schedule component. Slash marks on the observing records were initiated upon production of a red keylight and terminated by reinforced key responses. Unreinforced key responses occurred infrequently and are not shown.

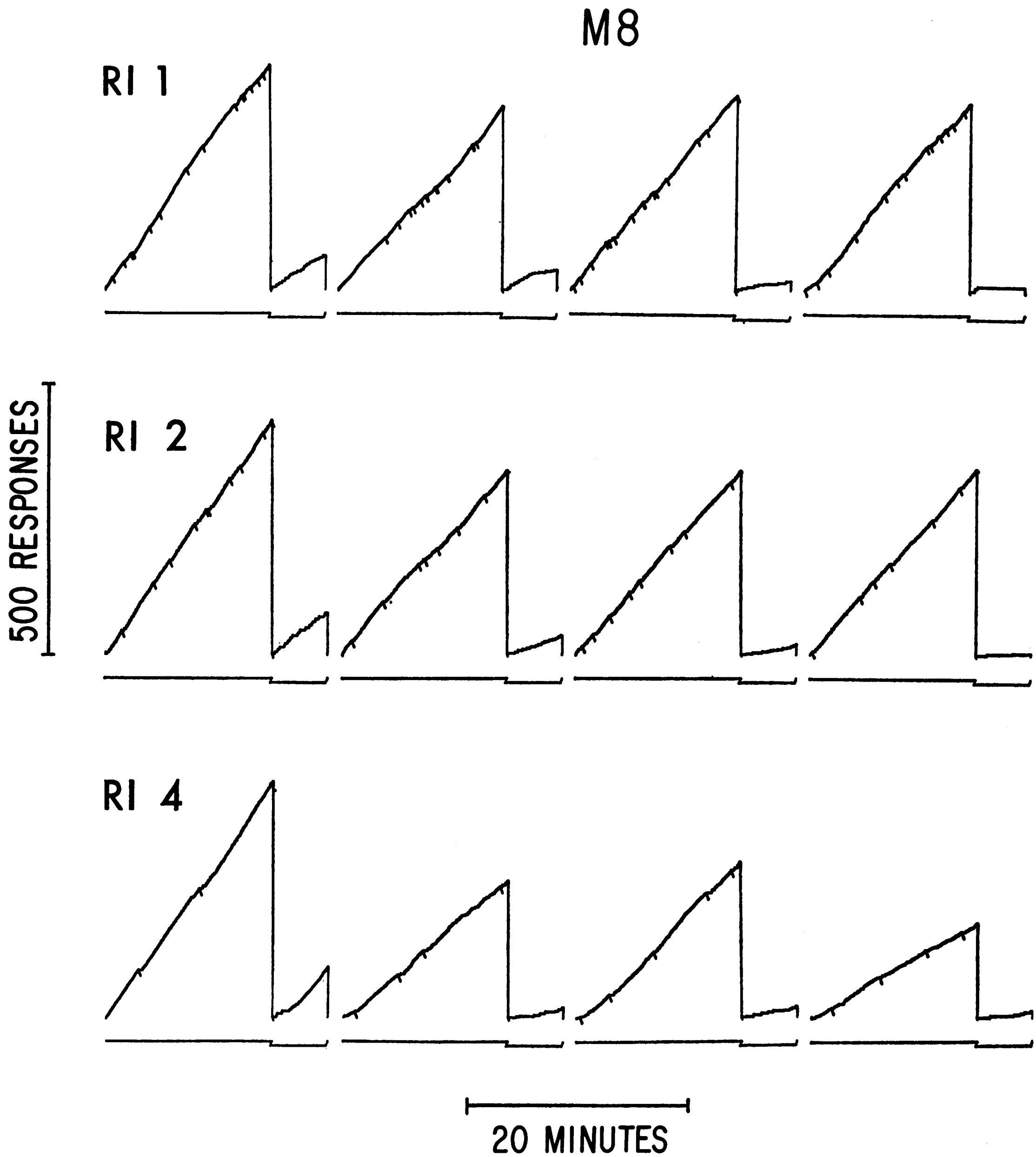

Fig. 2. Observing behavior of Monkey M8 during the ninety-fifth session under the multiple schedule. The record is arranged and labelled as in Fig. 1.

ever, the separation between observing rates under different schedules did not increase within the first 100 sessions. Both monkeys displayed about the same observing rate under RI 1-min and RI 2-min. Response rates were lower in RI 4-min and least in observing extinction. The similarity of rates under RI 1-min and RI 2-min may be related to the greater similarity of the two tones used as discriminative stimuli for these schedule components.

When the green light (S^{Δ}) was removed during extinction periods (at A in Fig. 3 and 4) observing rates in extinction continued to decrease. The decline in observing extinction continued gradually over the 20 sessions during which lever responses in that component produced no keylights. Reinstatement

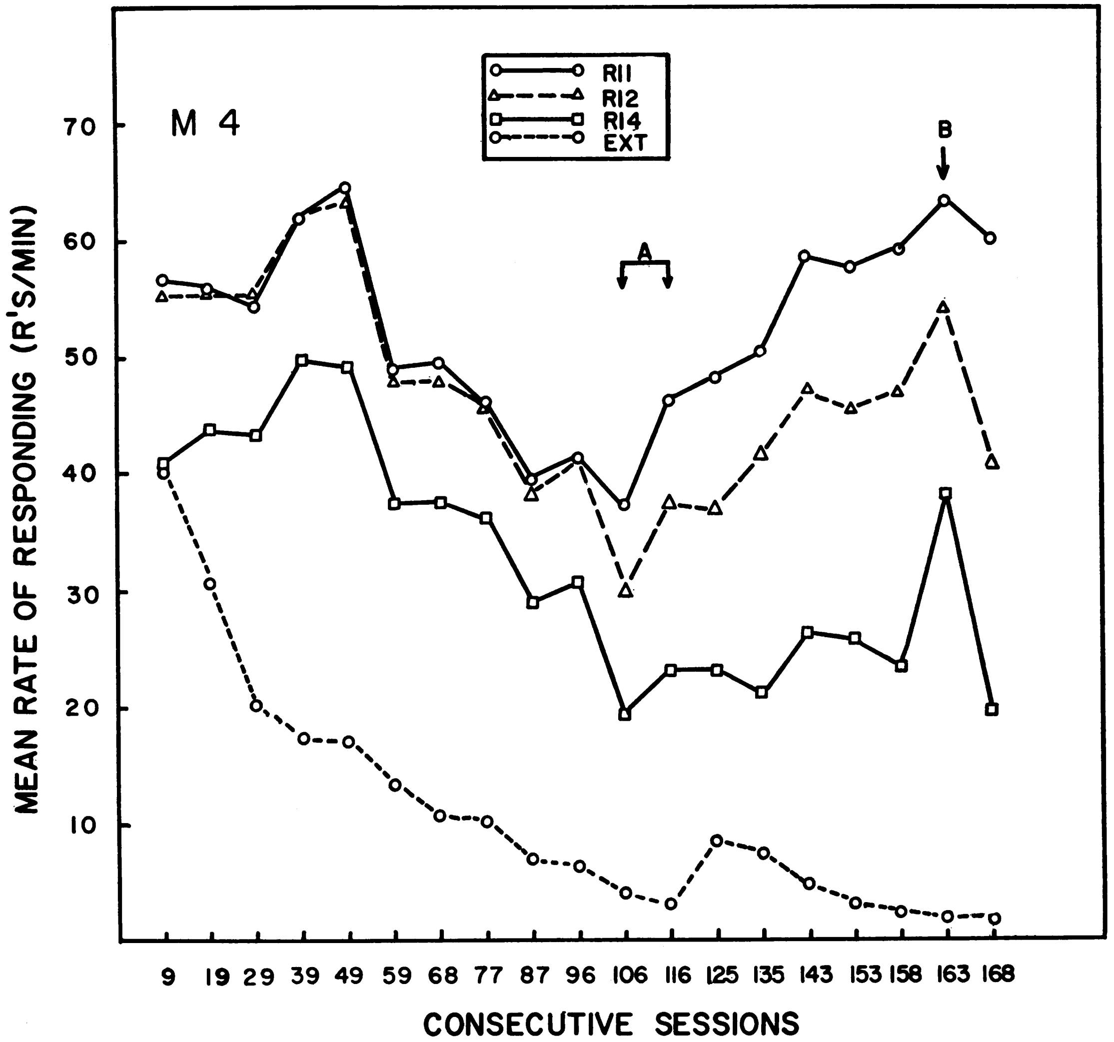

Fig. 3. Development of responding on the observing lever for Monkey M4. Mean rate of responding in each component of the multiple schedule is plotted as a function of cumulative number of sessions. Mean rates were obtained daily and the mean of these means computed over 10 sessions except as indicated on the abscissa. The last three sets of points are means of five sessions (one week). Because of malfunctions, several other points, as indicated on the abscissa, represent only nine sessions. At A, after 96 sessions, the green stimulus indicating unavailability of food was eliminated from the extinction component for 20 sessions. After 116 sessions, the green light in extinction was reinstated. At B, the green stimulus was eliminated in all schedule components for five sessions and then reinstated.

of response-produced S^{Δ} in extinction led to an immediate increase in observing in that component. A clear separation in observing rates under RI 1-min and RI 2-min also developed in M4 for the first time during the 20 sessions without S^{Δ} in extinction (at A in Fig. 3). This separation also persisted after the brief stimulus was reinstated in extinction. Thus, separation of observing rates under all four schedule components occurred in M4 only after S^{Δ} was removed from the extinction component; this did not occur with M8.

After reintroducing the brief response-produced S^{Δ} in extinction, 42 additional sessions were given under the original multiple schedule. When the brief stimulus indicating unavailability of food was then removed from all schedule components (at B in Fig. 3 and 4), the observing rate of M4 (Fig. 3) increased in the random-interval components but not

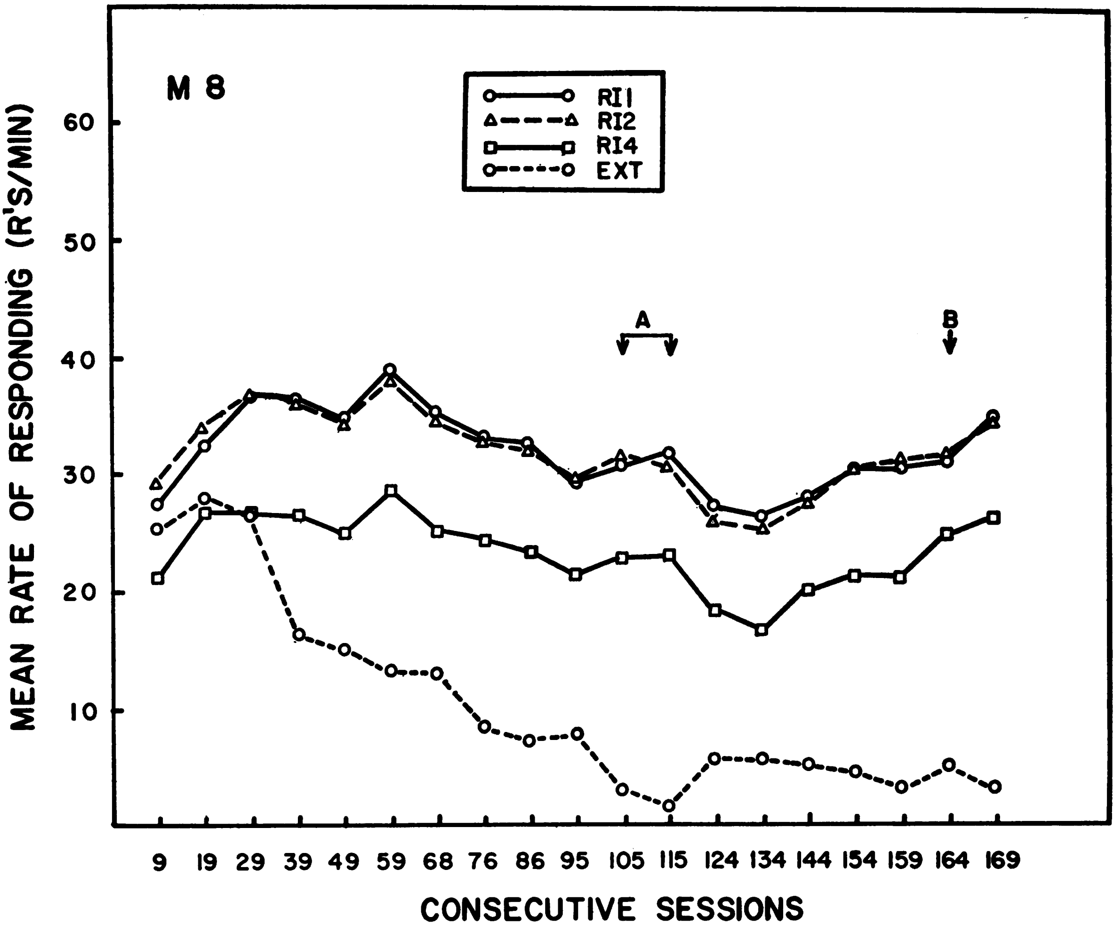

Fig. 4. Development of responding in each schedule component for Monkey M8. The data are plotted as in Fig. 3. Except as indicated on the abscissa, each point is the mean observing rate in one component for 10 consecutive sessions. At A, after 95 sessions, the food-unavailable stimulus (green light) was eliminated from the extinction component for 20 consecutive sessions. At B, after 159 sessions, the green stimulus was eliminated from all schedule components for five sessions.

in extinction. In this animal, reinstatement of S^{Δ} at B was followed by a return to previous levels of responding in all components. The increased rates seen in M4 upon removal of S^{Δ} from RI components were probably due to removal of the "pacing" effect that the brief stimulus has at high observing rates (de Lorge, *et al.,* 1967). A similar effect was not seen in M8 (at B in Fig. 4), whose observing rates were much lower under RI 1-min and RI 2-min.

The upper portion of Fig. 5 shows the mean rate of lever (observing) responses as a function of the S^D or reinforcement rate under all four schedule components. Data points for both subjects are means of the last 10 sessions before manipulation of S^{Δ} at A in Fig. 3 and 4. It is apparent that the observing rate of both subjects was an increasing function of reinforcement rate up to 30 reinforcements per hour (RI 2-min). These results are in contrast to those of the earlier experiment with the same subjects and schedules (de Lorge *et al.,* 1967).

The lower portion of Fig. 5 shows the key response rate of each monkey as a function of reinforcement rate. Data are from the same sessions as in the upper frame. The data of M4 lie just below a diagonal which is the locus of the reciprocal mean interreinforcement availability time. In other words, M4 almost never responded on the key except when it was lighted red and reinforcement was available. Monkey M8's key rate, how-

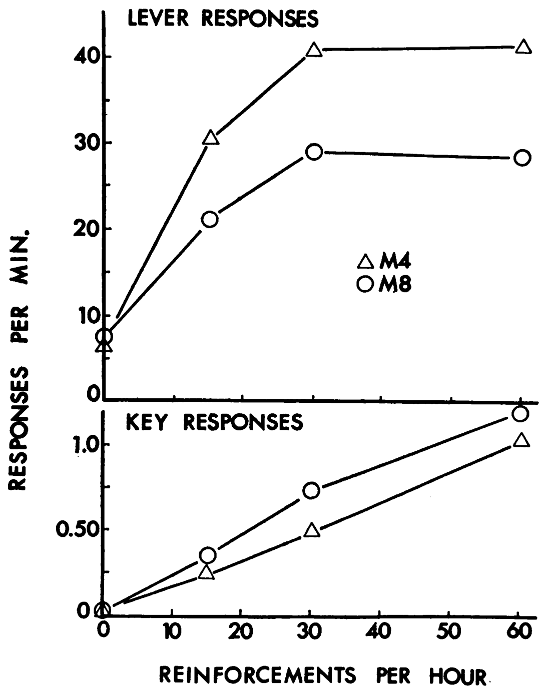

Fig. 5. Mean rate of the lever (observing) and key responses as functions of the reinforcement rate in the four components of the multiple schedule. Each point is the average rate for the last 10 sessions before any experimental manipulation.

ever, exceeded the rate of reinforcement by a small amount under all three RI schedules. That is, M8 emitted a few responses on the key in the absence of S^D. In two previous experiments (Clark, 1969; de Lorge *et al.*, 1967) M4 always emitted "extra" key responses at a substantial rate. The maintenance of responses to the key in the absence of S^D has been discussed previously (Clark, 1969). The disappearance of this behavior in M4 during the present experiment (after a total of nearly 300 sessions under observing procedures) may be related to the presence of an extinction component in the multiple schedule. Responses to the key were almost never emitted during extinction by either monkey.

DISCUSSION

In this experiment, observing rates were an increasing function of the rate at which S^D could be produced when several schedules were presented in the same session and coördinated with different stimuli. Within-session decrements in observing rate as a function of elapsed time were also obtained. When the brief response-produced S^Δ was removed from the extinction component, observing rates in extinction continued to decrease. These rates increased when S^Δ was subsequently reinstated.

The orderly relation of observing rate to S^D frequency in this experiment was absent in the earlier experiments (de Lorge *et al.*, 1967). In those experiments, the same S^D frequency obtained throughout a session and the schedule was manipulated sequentially from RI 1-min through RI 8-min after stabilization under each schedule. Under those conditions, the observing rate of M4 decreased from RI 2-min to RI 4-min, but much less than in the present experiment. And the observing rate of M8 actually increased from RI 1-min through RI 4-min in the earlier experiment. The present results support our previous conjecture that observing rates correspond to S^D frequency only where different frequencies are simultaneously available, as in a concurrent schedule, or alternately available, as in a multiple schedule. A similar suggestion has been made regarding the relation of response rate to reinforcement rate where observing behavior is not in question (Catania, 1966; Herrnstein, 1961; Morse, 1966). The present results suggest this may be related to the presence of explicit discriminative stimuli for different reinforcement densities.

The decreases in observing rate with elapsed time shown in Fig. 1 and 2 occurred after daily average rates had stabilized. The conditions responsible for such decrements are unclear. They were not obtained in the earlier experiments with 2-hr sessions (Clark, 1969; de Lorge *et al.*, 1967). Nor have they occurred in other observing response experiments (*e.g.*, Kelleher *et al.*, 1962). Perhaps such decreases occur only in long sessions with low reinforcement densities.

When brief response-produced stimuli indicating food unavailability (S^D for the key response) were removed from the extinction component of the multiple schedule, observing rates in extinction continued decreasing. When S^D was again made available in extinction, observing rates in that component increased abruptly. A similar manipulation later in the experiment did not have the same effect, but at that time observing rates in extinction were so low that S^Δ was rarely produced. The increase in observing after reinstatement of the brief S^{Δ} in extinction suggests that the occurrence of this stimulus had a role in maintaining observing responses. Hendry and Coulbourn (1967), Schaub (1969), and Schaub and Honig (1967) suggested that a stimulus correlated with extinction can reinforce observing responses. This question has been discussed recently by Gollub (1970). Under the procedure of the present experiment, however, effects of the brief S^{Δ} on the maintenance of observing responses can be related to discriminative functions of that stimulus. The occurrence of S^{Δ} increased the similarity of stimulus conditions obtaining across schedule components. Observing responses produced S^{Δ} for the key response on a schedule approaching continuous reinforcement. At the same time, observing was reinforced with S^{D} for the key response at random intervals. Production of S^{Δ} was an occasion for non-reinforcement of key responses and controlled a very low rate of that response. A brief S^{Δ}, however, was an occasion upon which subsequent observing responses were intermittently reinforced by production of S^{D} for reinforcement of the key response. Thus, while brief S^{Δ}s were not occasions for reinforcement of key responses they were occasions for intermittent conditioned reinforcement of subsequent observing responses. While special properties of S^{Δ}, such as its "information value", might be invoked to account for its role in the maintenance of observing behavior, these are unnecessary in the present context. After our earlier experiments we were tempted to say that the subjects responded so as to keep the key lighted regardless of the frequency of red lights. But in this experiment the observing rate ("tendency to keep the key lighted") varied with the frequency of S^{D}.

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